INDOOR AIR QUALITY ASSESSMENT

Wales Town Hall
3 Hollow Road
Wales, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
August 2003

Background/Introduction

At the request of the Wales Board of Health, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Wales Town Hall (WTH), 3 Hollow Road, Wales, Massachusetts. Concerns about odors identified around the front door/foyer prompted the request. On May 12, 2003, a visit to conduct an indoor air quality assessment was made to this building by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ).

The WTH is a two-story, wood clapboard building originally constructed as a school. The building was renovated during the 1970s and converted into town offices. The first and second floors serve town offices, as well as the main office of the Wales Police Department. The basement is unoccupied and is only used as storage for town records. A boiler room and crawlspace exist in opposite ends of the basement. Windows appear to be original wooden sash windows, which are openable throughout the building.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551.

Results

The WTH has an employee population of 6 and is visited by approximately 25 to 30 people daily. Tests were taken during normal operations and results appear in Table 1. It is important to note that the police department office on the second floor could not be accessed during the assessment.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million of air (ppm) in all occupied offices, indicating adequate ventilation in the building. However, it is important to note that all of the areas were sparsely populated and/or had windows open during the assessment, which can greatly reduce carbon dioxide levels. Carbon dioxide levels in the building would be expected to be higher during winter months, when windows and exterior doors are closed.

No mechanical supply or exhaust ventilation systems exist in the WTH. Fresh air ventilation is provided by windows. Prior to the renovation, ventilation during summer months was controlled by the use of openable windows. The building was configured in a manner to use cross-ventilation to provide comfort for building occupants. The WTH is equipped with windows on opposing exterior walls. This design allows air to enter an open window, pass through a room, pass through an open interior door, enter the hallway, pass through the opposing room's interior door, into the opposing room and exit the building on the leeward side (opposite the windward side) (Figure 1). With all windows and interior doors open, airflow can be maintained in a building regardless of the direction of the wind. The system fails if the windows or interior doors are closed (Figure 2). During renovations in the 1970s, classrooms were subdivided by walls erected to create office space. The current room reconfiguration can impede airflow if hallway doors are closed.

It appears that the building was originally equipped with a gravity exhaust ventilation system (Pictures 1-3). No airflow was detected in any of the exhaust vents examined. A louver located inside the duct controls airflow. Above the louver is usually a heating element that creates airflow that would exit the building through an airshaft via rising heat. This process is referred to as the "stack effect." It is possible that exhaust air is removed from the building by a deactivated fan/motor located in a cupola on the roof (see Picture 4). Based upon these observations, it appears that the building does not have a functioning exhaust ventilation system. Without exhaust ventilation, normally occurring environmental pollutants can build up and lead to air quality/comfort complaints.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health

Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings ranged from 62^{o} F to 65^{o} F, which were below the BEHA recommended comfort guidelines. Please note that the furnace was deactivated during the assessment. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is difficult in an old building without a functioning ventilation system and/or the boiler plant deactivated.

The relative humidity ranged from 39 to 49 percent in occupied areas, which was within the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Please note relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment.

Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As previously mentioned, building occupants identified odors localized around the front door and foyer/first floor hallway. The origin of the odors reported by WTH occupants appears to be the basement/crawlspace area located beneath the first floor. These odors may stem from two possible sources:

- mold contamination of paper, cardboard and dirt in the basement/crawlspace area; and/or
- products of combustion from the boiler room.

This section of the assessment will detail findings concerning water damaged materials. (The discussion concerning products of combustion is found in the **Other Concerns** section of this report).

Several sources for water penetration exist in the basement crawlspace. A PVC pipe was found suspended in the basement (see Picture 5). Heavy water stains were noted beneath the pipe. The pipe was traced from a location in the foundation beneath fiberglass insulation and a wooden board (see Picture 6) to a dry well located uphill from the WTH (see Pictures 7 and 8). Accumulated water against the foundation can penetrate into the basement around the PVC pipe hole. Wales town officials believe that this pipe was installed as part of a groundwater monitoring system to evaluate a chemical spill located uphill from the WTH (see Picture 9). Wales town officials report that an environmental consulting firm had removed equipment from the basement, allegedly leaving behind the PVC pipe. Two likely sources for water infiltration include: directing of water from the drywell into the basement via the pipe and rainwater penetrating through the foundation along the pipe.

The gutter/downspout system also plays a role in allowing moisture to penetrate into the basement/crawlspace. A downspout empties into a trough-like area, which directs rainwater against the foundation (see Picture 10). Over the years, this run-off has created a trench around the base of the wall. This trench allows rainwater and melting snow to pool against the foundation. In addition, the shrubbery growing against the foundation wall (Picture 11) can bring moisture from roots into contact with wall-brick. Eventually, the roots cause cracks and/or fissures in the foundation below ground. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building via capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

Condensation generated during hot, humid weather may be another source of moisture in the basement. Condensation is the collection of moisture on a surface that has a temperature below the dew point. The dew point is a temperature that is determined by air temperature and relative humidity. For example, at a temperature of 76^{o}F and relative humidity of 30 percent, the dew point for water to collect on a surface is approximately 43^{o}F. At a temperature of 85^{o}F and relative humidity of 90 percent, the dew point for water to collect on a surface is approximately 82^{o}F. If a surface has a temperature under 83^{o}F, water vapor in the air in contact with that surface will condense and form droplets. Surfaces below grade that are in contact with earth, tend to be substantially cooler than the ambient air temperature. As a result, below grade surfaces are prone to generating condensation.

During the summer of 2002, New England experienced stretches of excessively humid weather. For example, from July 4, 2002 through July 12, 2002, weather conditions produced an outdoor relative humidity that, at various times, ranged from 73 to 100 percent, without precipitation (The Weather Underground, 2002). According to ASHRAE, if relative humidity exceeds 70 percent, mold growth may occur due to wetting of building materials (ASHRAE, 1989). The basement is used for storage of large amounts of materials, including cardboard and paper products (see Picture 12). If these materials, subjected to high relative humidity conditions and are not dried for several days, then these materials would likely be colonized by fungi (mold). High ambient temperature and relative humidity during the summer combined with water sources within the basement, may contribute to moistening of porous materials. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 hours of becoming wet (US EPA, 2001, ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur.

In order to explain the migratory pathways of mold and mold associated odors, the following concepts must be understood:

- Heated air (from radiators) will create upward air movement (called the stack effect).
- Heated air from the boiler room escapes through the fire door and moves up the stairwell.

- Cold air moves to hot air, which creates drafts.
- Heated air rises, creating negative pressure is created, which draws cold air to the heat source.
- Airflow created by the stack effect, drafts or mechanical ventilation can draw airborne particulates into the air stream (i.e. from the basement).
- Open doors to the basement from the main stairwell can provide a pathway for air to travel from the basement to the upper floors.

Each of these concepts can influence the movement of basement odors and/or particulates up the stairwell. In order to control possible mold growth, water penetration into the basement area must be minimized. Control of water penetration through the foundation can be limited by removing plants, redirecting rainwater from foundation contact and sealing/removing the PVC pipe.

Other potential sources of mold growth were noted. Water damaged ceiling tiles were noted in some areas, which are evidence of historic roof or plumbing leaks. Water-damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired.

Other Concerns

As previously discussed, combustion products may also contribute to odors identified by building occupants. Odors are produced by the four gas-fired boilers located in the basement. Although the boilers are equipped with a ventilation system, odors can escape from and migrate into occupant areas. As the boilers operate during the heating season, products of combustion can escape from the exhaust system via holes in ductwork that connect the boilers to the chimney. Odors can then migrate upstairs through unsealed, abandoned heating system pipes. As with mold odors, combustion odors can also migrate into occupant areas by way of the basement stairwell. Products of combustion can accumulate at the top of the doorway to the basement staircase under these circumstances. Odors would penetrate into the hallway either through breaches in the basement stairwell ceiling (Picture 15) or through the opened basement door.

The boilers are vented to a chimney by horizontal ductwork (see Picture 16). The duct connecting the boilers to the chimney is approximately 12 feet in length and has an estimated total of 360^{o} in turns. In general, exhaust duct configuration should minimize the numbers of horizontal pipes and turns. With every 90^{o} angle that exists in the ductwork, airflow is decreased in half. Increasing length and turns in exhaust ductwork can decrease the exhaust efficiency of the ventilation. If this occurs, products of combustion can pool in the ducts and a buildup of soot would occur. Soot accumulation is a sign of decreased draw by the exhaust vent duct. Accumulated soot was observed on the boiler cabinet, below the vent bell (see Picture 17). Additionally, water vapor mixing with other products of combustion can create corrosive materials that can degrade the metal of the ductwork.

The process of combustion produces a number of pollutants. Products are dependant on the composition of the material. Common combustion emissions can include carbon monoxide (CO), water vapor, smoke, as well as carbon dioxide (CO_2). Of these materials, CO can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning CO in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a

CO level over 30 ppm taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce CO levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to CO in outdoor air. CO levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard. These NAAQS are used by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) as measures for assessing indoor air quality in buildings (ASHRAE, 1989).

In order to provide efficient combustion for the gas jet in the boiler, an adequate supply of combustion air is needed to provide oxygen. A make up air vent is usually located in an area near the furnace. The combustion air vent (window) for the furnace was sealed (see Picture 18). With the window closed, combustion air is drawn from the interior of the building. This condition can result in incomplete combustion of fuel, which can produce by products such as CO. Holes in the boilers' exhaust vent allow for the escape of CO into the boiler room. For this reason, CO measurements were taken in the basement prior to and after activation of the hot water heater. No detectable levels of CO were measured at any time during the assessment. Of note was the concentration of carbon dioxide levels in the boiler room when compared to outdoors. Carbon dioxide measurements in the basement were 300 ppm above outdoor levels. The basement air measurements indicate that a carbon dioxide production source, independent of occupancy, exists in the basement. This source is likely the pilot lights in each boiler.

Several other conditions that can affect indoor air quality were noted during the assessment. According to building occupants, the WTH has had problems with rodent infestation. Means of egress, such as holes in the foundation, were observed (see Pictures 19 and 20). As a result of materials present in wastes, rodent infestation can produce indoor air quality related symptoms. Mouse urine is known to contain a protein that is a known sensitizer (US EPA, 1992). A sensitizer is a material that can produce symptoms in exposed individuals (e.g. running nose or skin rashes). A three-step approach is necessary to eliminate rodent infestation:

1. Removal of the rodents;
2. Cleaning of waste products from the interior of the building; and
3. Reduction/elimination of pathways/food sources that are attracting rodents.

To eliminate exposure to allergens, rodents must be removed from the building. Please note that removal, even after cleaning, may not provide immediate relief since allergens can persist in the interior for several months after rodents are eliminated (Burge, 1995). A combination of cleaning and increasing of ventilation and filtration should serve to reduce rodent associated allergens once the infestation is eliminated.

Used ash trays were noted on the second floor of the WTH (see Picture 21). Environmental tobacco smoke can have a marked effect on indoor air quality. The most effective method of preventing exposure to environmental tobacco smoke is making buildings smoke free. M.G.L. Chapter 270, Sec. 22 prohibits smoking in public buildings, except in an area that has been specifically designed as a smoking area (M.G.L., 1987). The American Society of Heating, Refrigeration, Air-Conditioning Engineers (ASHRAE) recommends a ventilation rate of 60 cubic feet per minute per occupant in smoking lounges (ASHRAE, 1989). The ASHRAE recommendation is designed to prevent odors of cigarette smoke from penetrating areas outside the designated smoking area.

Open pipes from an abandoned heating system were noted in a number of areas (see Picture 22). Open pipes and spaces around pipes can serve as pathways for dust, dirt, odors and other pollutants to move from the floor/wall cavities into occupied areas.

A sewer pipe cleanout appears to be sealed by the insertion of a plastic bottle (see Picture 23). Sewer gas is an eye, nose and respiratory irritant. Sewer pipes should be capped appropriately to prevent odor back up into the boiler room.

Conclusions/Recommendations

The most likely origin of odors in the WTH is a result of basement air migrating into occupied areas. The lack of combustion air for boilers, presence of holes in the boiler exhaust duct and lack of draw of boiler exhaust vents produce conditions where products of combustion accumulate in the basement stairwell. Based on the observations made during the assessment, the following recommendations are made.

1) Install a wall-mounted CO alarm with digital readout in the basement stairwell. CO levels should be checked daily after the boiler is fired up during the heating season.
2) Seal all holes and seams in the boiler ducts to prevent CO penetration into occupied space.
3) Reduce the length and number of bends (turns) in the boiler vent.
4) Install a power fan on each duct in the ductwork/chimney to facilitate removal of pollutants to the outdoors.

5) Provide adequate combustion air to for the boilers. Consider reconfiguring the window in the boiler room to provide combustion air. Consult with the local fire prevention officer/building code officials to determine an appropriate method to provide combustion air for the boilers.

6) Consider rendering the boiler room and entrances to the basement as airtight as possible to eliminate the migration of combustion air to occupied areas after an adequate combustion air source for the boilers is established. These measures would include:

    a) Install weather-stripping around the doorframe of the basement access door, as well as a door sweep at the bottom of the door.

    b) Seal the holes in the ceiling

    c) Sealing the spaces around utility pipes that enter the occupied space through the floor.

    d) Seal all abandoned heating pipes.

7) Prevent water penetration into the basement. The following steps may be taken to prevent rainwater from downspouts and exterior wall runoff from penetrating through the foundation.

    a) Examine the feasibility of directing downspout water away from the base of the foundation wall at the rear of the building.

    b) Improve the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek & Brennan, 2001).

    c) Move foliage to a minimum five feet away from the foundation.

d) Install a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek & Brennan, 2001).

8) Remove the PVC pipe and reseal the wall of the dry well and foundation.
9) Seal all holes in the exterior walls of building to prevent mouse and other rodent migration.
10) Remove mold colonized materials from the basement. Disinfect non-porous surfaces with an appropriate antimicrobial. If more extensive water damage/mold growth is found, remove mold-contaminated materials in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency (US EPA, 2001). Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html
11) Replace water damaged ceiling tiles.
12) For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
13) Use the principles of integrated pest management (IPM) to rid the building of pest. A copy of the IPM recommendations can be obtained from the Massachusetts Department

of Food and Agriculture (MDFA) website at the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf. Activities that can be used to eliminate pest infestation may include the following activities.

a) Rinse out recycled food containers. Seal recycled containers in a tight fitting lid to prevent rodent access.
b) Remove non-food items that rodents are consuming.
c) Stored foods in tight fitting containers.
d) Avoid eating at workstations. In areas were food is consumed, periodic vacuuming to remove crumbs are recommended.
e) Regularly clean crumbs and other food residues from toasters, toaster ovens, microwave ovens coffee pots and other food preparation equipment;
f) Holes as small as ¼" are enough space for rodents to enter an area. Examine each room and the exterior walls of the building for means of rodent egress and seal. If doors do not seal at the bottom, install a weather strip as a barrier to rodents.
g) Reduce harborages (cardboard boxes) where rodents may reside (MDFA, 1996).

14) Comply with Massachusetts General Law Chapter 270, Sec. 22 (i.e., smoking in public buildings).
15) For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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Picture 1

Gravity Exhaust Ventilation System, Second Floor

Picture 2

Gravity Exhaust Ventilation System, Second Floor

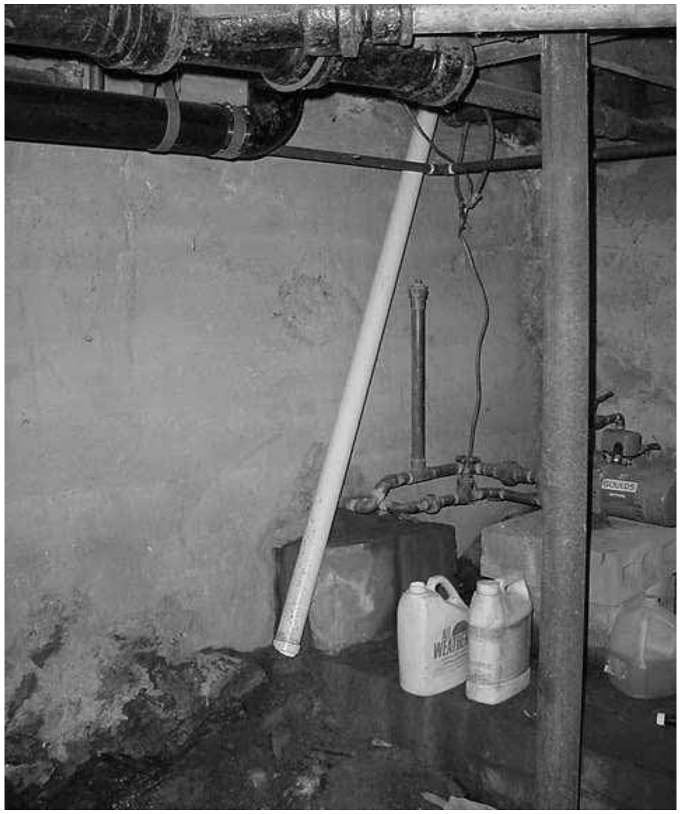
Picture 3

Gravity Exhaust Ventilation System, First Floor

Picture 4

Exhaust Vents in Cupola on Roof

Picture 5



Abandoned PVC Pipe in Basement

Picture 6

PVC Pipe in Picture 5 Traversing the Foundation Wall

Picture 7

Dry Well

Picture 8

Hose and Wiring Inside Of Dry Well Wall

Picture 9

Monitoring Well At Corner of Property

Picture 10

Downspout Emptying against Crawlspace Section of Foundation

Picture 11

Shrubbery against the Foundation Wall

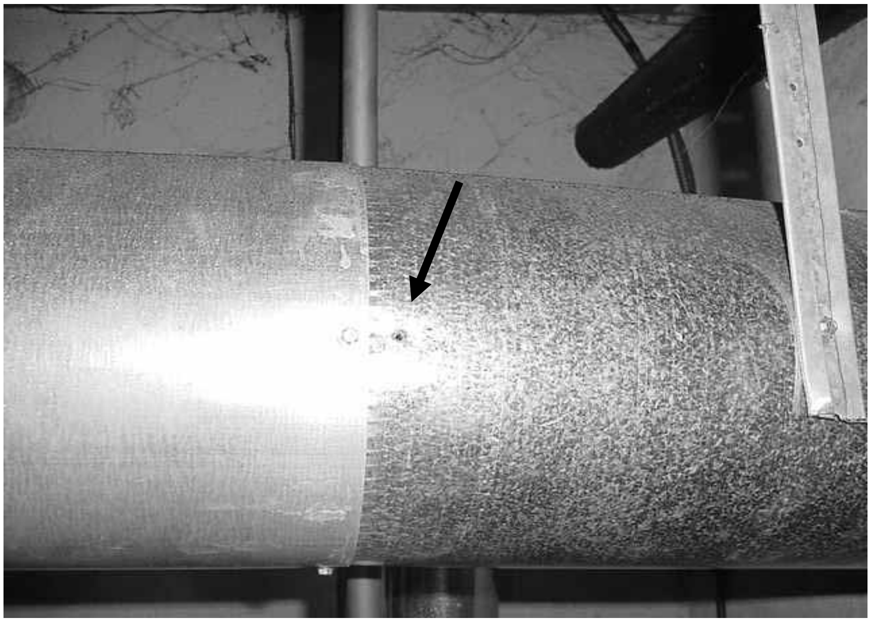
Picture 12

Materials Stored in Basement, Notes Water Stains On Boxes in Contact With Floor

Picture 13

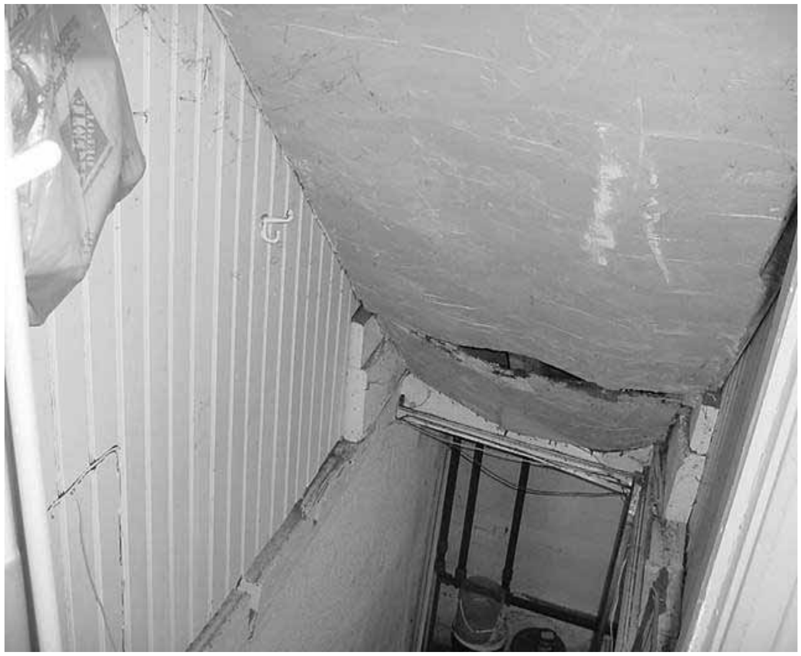
Boilers in Basement

Picture 14a



Holes Were Noted In the Duct Connecting the Boilers

Picture 14b



Beaches in the Basement Stairwell Ceiling

Picture 15a

Chimney Horizontal Ductwork

Picture 15b

Soot Accumulation below Exhaust Vent Bell

Picture 16

Combustion Air Vent for Boilers

Picture 17

Holes in the Foundation

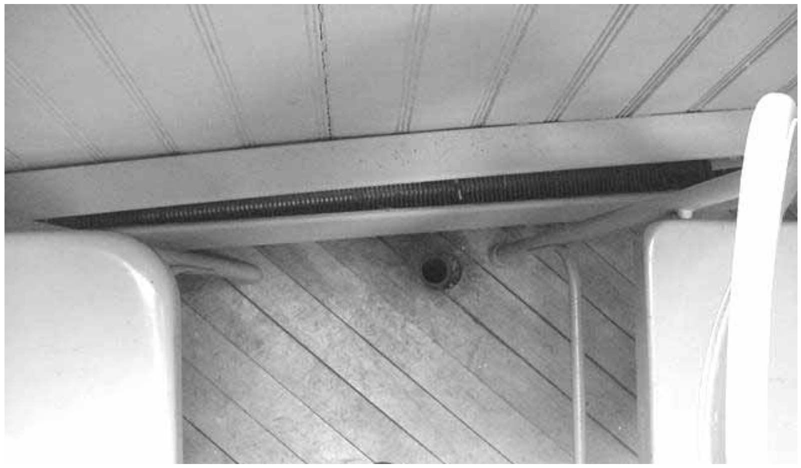
Picture 18

Holes in the Foundation

Picture 19

Used Ash Trays

Picture 20



Open Pipes of an Abandoned Heating System

Picture 21

Sewer Pipe with Plastic Bottle Inserted into the Cleanout Opening

TABLE 1

Indoor Air Test Results – Wales Town Hall, Wales – Massachusetts **May 12, 2003**

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	304	59	43					
Tax Collector	509	63	49	1	Y	N	N	Stove exhaust 6 CT
Town Accountant	953	64	45	0	Y	N	N	6 CT
Board of Selectmen	719	62	49	2	Y	N	N	Plants Old pipe for radiator
Town Clerk	752	65	48	1	Y	N	N	Door open 2 CPU
Planning Board	476	65	43	0	N	N	N	Door open; sealed pot-belly stove exhaust, exhaust louver closed
Cemetery Commission	554	65	39	0	Y	N	N	
Conservation	461	65	43	0	Y	N	N	
Meeting Room	557	64	42	0	Y	N	Y	Door open; holes in floor 4 CT – holes flow
Board of Health	543	65	42	0	Y	N	N	Passive vent to store room; water damaged plaster Insulation on floor
PUPC								Potbelly stove vent

*** ppm = parts per million parts of air**
CT = water-damaged ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

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Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Basement	331	58	52	0	N	N	N	Wet cardboard
Boiler	609	58	60	0	N	N	N	Holes in exhaust vent pipe; no make up air vent open; pipe plugged with plastic bottle
PUPC	480	65	43	0	N	N	N	

*** ppm = parts per million parts of air**
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